Symposium 17: Bridging the gap between experiments and theories (Sat July 31, 14:00-16:00 JST)
Chair: Se-Bum Paik (Korea Advanced Institute of Science and Technology, Daejeon, Korea)

14:00-14:30 Kenji Doya (Neural Computation Unit, Okinawa Institute of Science and Technology Graduate University, Japan)
The duality of control and inference as a clue for cracking the codes of frontal and sensory cortical architectures

14:30-15:00 Tatyana O. Sharpee (Salk Institute for Biological Studies, USA)
Reading out responses of large neural population with minimal information loss

15:00-15:30 Se-Bum Paik (Korea Advanced Institute of Science and Technology, Daejeon, Korea)
Emergence of cognitive functions in untrained neural networks

15:30-16:00 Li Zhaoping (Univ of Tübingen and Max Planck Inst for Biological Cybernetics, Germany)
From V1SH to CPD, a new framework for understanding vision.

Symposium 17 Speaker 1
Kenji Doya
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The duality of control and inference as a clue for cracking the codes of frontal and sensory cortical architectures

The duality of optimal control and sensory inference has been known since the days of Kalman (1960), and it has recently been recognized as common computations required for the value function in reinforcement learning and the log posterior distribution in dynamic Bayesian inference. Meanwhile, an intriguing question in brain science is why does the whole cerebral cortex have a common six-layer architecture, while its anterior and posterior halves are engaged in motor control and sensory processing, respectively.
Here we consider a hypothesis that the anterior and posterior cortical circuits evolved for dual computations of reinforcement learning and sensory inference, or value-based and perceptual decision making, respectively. We explore how different types of cortical neurons may represent different variables, such as prior and posterior distributions and value functions, and what cortical dynamics may realize computations, such as model-based prediction, Bayesian integration, and action selection. We further discuss what experimental and computational approaches are required for scrutinizing this dual cortical circuit hypothesis.

Symposium 17 Speaker 2
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Reading out responses of large neural population with minimal information loss

Classic studies show that in many species – from leech and cricket to primate – responses of neural populations can be quite successfully read out using a measure neural population activity termed the population vector. However, despite its successes, detailed analyses have shown that the standard population vector discards substantial amounts of information contained in the responses of a neural population, and so is unlikely to accurately describe how signal communication between parts of the nervous system. I will describe recent theoretical results showing how to modify the population vector expression in order to read out neural responses without information loss, ideally. These results make it possible to quantify the contribution of weakly tuned neurons to perception. I will also discuss numerical methods that can be used to minimize information loss when reading out responses of large neural populations.

Symposium 17 Speaker 3

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Emergence of cognitive functions in untrained neural networks

Model studies using biologically inspired artificial neural networks have provided insight into the underlying mechanisms of brain functions, particularly regarding the development of various functional circuits for visual information processing. Recent studies revealed that various visual functions can emerge from supervised and unsupervised learning, suggesting a possible mechanism of how visual object recognition in the brain arises initially. However, the ability to perform various cognitive functions is often observed in naïve animals, and this raises questions about the origin of early cognitive functions in the brain. Here, we suggest that visual cognitive functions such as number sense or face detection can emerge spontaneously in hierarchical neural networks in the complete absence of visual training. Using a biologically inspired deep neural network, we found that neurons tuned to face images or stimulus numerosity arise in untrained random feedforward networks. These neurons also showed single- and multi-neuron characteristics of the types observed in biological brains. The responses of these neurons enable the network to perform a visual comparison task, even under the condition that the information in the stimulus is incongruent with low-level visual cues. These results suggest that cognitive functions can emerge from the statistical properties of bottom-up projections in hierarchical neural networks, and provide new insight into the origin of early cognitive functions in biological brains, as well as in artificial deep neural networks.

Symposium 17 Speaker 4
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From V1SH to CPD, a new framework for understanding vision.

V1SH is the V1 Saliency Hypothesis, and CPD is the Central-Peripheral Dichotomy.
I will explain how they motivate a new framework: Visual attention selects only a tiny fraction of visual input information for further processing. Selection starts in the primary visual cortex (V1), which creates a bottom-up saliency map (V1SH) to guide the fovea to selected visual locations via gaze shifts. This motivates a new framework that views vision as consisting of encoding, selection, and decoding stages, placing selection on center stage. It suggests a massive loss of non-selected information from V1 downstream along the visual pathway. Hence, feedback from downstream visual cortical areas to V1 for better decoding (recognition), through analysis-by- synthesis, should query for additional information and be mainly directed at the foveal region (CPD). Accordingly, non-foveal vision is not only poorer in spatial resolution, but also more susceptible to many illusions. Some background/details are in http://www.lizhaoping.org/zhaoping/NewPathPaperEtc_2019.html I will also show the latest findings, including a peripheral illusion predicted by this framework and a stereo vision paradigm as an example to investigate the analysis-by-synthesis process in the top-down feedback for visual inference in central vision.